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CRITICAL ANALYSIS OF PRODUCTIVITY MODELS AND MEASUREMENT IN INFORMATION PROCESSING

by

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Foreword

This report presents the findings of a study on possible methods, methodologies and approaches for modelling and measuring the impacts of computerization in general, and the effects on organizational productivity of the introduction of computerized information processing in particular. The term "information processing" is used here in the broadest sense to include a range of technologies encompassing traditional computerized systems, management information systems and electronic office systems.

The findings of the study are based on an analysis of some of the scientific literature (books and articles in periodicals) or the "grey" literature (research reports, internal publications of certain organizations), on the results of some of my own projects (impact of computerization on small and medium-sized businesses, cost/benefit modelling of systems, EDP master plans), and of the results of a survey of large organizations.

Technology impacts on individuals, organizations and society in many complex ways, and it changes rapidly. To assess these impacts, it is therefore important to have a measurement tool independent of the characteristics of the technology that is sensitive to the different kinds of effects. From our research we were able to determine guidelines for such a tool that expresses these impacts in the form of economic indicators.

The research was carried out at the Canadian Workplace Automation Research Centre from September 1985 to February 1986, while the author was on sabbatical leave from Laval University.

We wish to thank the Canadian Workplace Automation Research Centre for the use of its facilities and for providing us with the wherewithal, both technical and financial, to complete this assignment, and to express our gratitude to the Director and staff of the Organizational Research Branch for many enriching discussions and much good advice. We would also like to express our gratitude to the many organizations and individuals too numerous to list here who provided us with the data used in this research.

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1. Introduction

On sabbatical leave from the Department of Computer Science, Laval University, we spent six months from September 1985 to February 1986 at the Canadian Workplace Automation Research Centre (CWARC), an arm of the federal Department of Communications. The main objective was to develop a tool to measure organizational productivity with regard to computerization.

Secondary objectives were to study the links between the various forms of computerization and the different categories of users, the impact of computerization on user productivity, productivity gains in terms of overall system benefits, the impact of individual productivity on organizational productivity, the impact of organizational productivity on industrial productivity and to determine conditions under which productivity measurement can be applied.

To achieve these objectives, our main approach was to review the scientific literature on the subject and to analyse the results of various related research projects; some of these we carried out ourselves and others were large-scale initiatives launched by the Government of Canada: the Office Communications Systems (OCS) Program of the Department of Communications and the Treasury Board Task Force on Informatics. We also studied many documents, a list of which appears in Chapter 10. We also identified other documents, or colleagues suggested other material to us, some of which we have only looked at superficially and could be worth analysing in greater depth; a list of these appears in Chapter 11. We also prepared another CWARC research report [ARDOP03] on these bibliographical references.

Over the last two years, we have conducted or collaborated in various research studies on organizational productivity in relation to information technology on respectively the impacts of computerization on small and medium-sized businesses, the development and validation of a cost/benefit model for information systems, and the analysis of the main characteristics of EDP master plans. The main lines of some of these projects and their chief findings are given later in this report.

Although the scientific literature describes many models, it offers very few that have in fact been applied and that have produced measurements that are sufficiently valid to be transposed to other contexts. This is also true of the results of the work done under the OCS Program. We were only able to consult a few of the reports produced by the Task Force on Informatics, since their distribution was restricted by Treasury Board.

There are models that predict the macroeconomic impact of computerization (e.g., jobs created, balance of payments) and the microeconomic impact (e.g., improved efficiency of secretaries as a result of word processing systems), but between these two extremes there is a dearth of quantitative data on productivity measurement. Furthermore, various authors point out that computerization impacts on various levels, such as the quality of working life or employee motivation, that are difficult to measure.

Initially we thought that we would be able to identify a general approach to productivity assessment in relation to information processing in most organizations, by synthesizing the results from various sources. Toward the end of 1985 we felt that, for the above reasons, there was not enough information available to lay the groundwork for the desired approach.

In January and February 1986, in order to have a better overall view of the subject, we conducted a survey of large organizations in the Montreal area on how EDP planning and productivity measurement were carried out and to gather the opinions of EDP and user managers on certain related topics. Questionnaires were completed by EDP managers in 56 organizations; questions were asked on the organization (sales figures, number of employees), on EDP characteristics (staff, total budget and breakdown of major spending categories including office systems), the identification of formal EDP or EDP-related planning elements, and the identification of productivity components expressed in formal criteria.

Interviews with 15 EDP managers and 26 user managers yielded their opinions on the distinction between information processing and office automation, on how productivity can best be measured and expressed in economic terms, on how useful productivity measurement might be, on the human impacts and on measurement planning, on the role of users and on the use of measurement results. The detailed results of the survey are discussed in another CWARC research report [ARDOP04] and a summary is given in Chapter 5.

From the findings of this survey, in light of the results of federal government projects and our own projects, along with the synthesis we were able to obtain from the scientific literature on organizational productivity in relation to information processing, we were able to lay the groundwork for an economic approach to impact measurement in general and to productivity measurement in particular.

The rest of this report consists of seven chapters, followed by a short conclusion and lists of bibliographical references. Chapter 2 outlines Government of Canada projects under the Department of Communications' Office Communications Systems Program and the Treasury Board Task Force on Informatics. Chapter 3 discusses our study of the OCS Program: main lines, brief review of documents analysed, some interesting approaches we identified and a synthesis. Chapter 4 summarizes some of our own projects: impacts on small and medium-sized businesses, system cost/benefit model, master plans and survey of large organizations.

Chapter 5 gives the main characteristics of our survey on planning and productivity in information processing: general background, sample, planning, productivity measurement, respondents' views and findings. Chapter 6 describes our cost/benefit model, discussing its main lines and some mathematical aspects, with an example of how it can be applied and comments on the accuracy of its results. Chapter 7 summarizes our review of the scientific literature. Finally, Chapter 8 presents the main lines of the economic approach we propose.

2. Summary of Government of Canada projects

For many years, the Government of Canada has conducted comprehensive studies of various facets of informatics, which have led to the introduction of principles, guidelines and policies applicable to some or all government agencies. Mechanisms for the systematic dissemination of information have been put in place through the production of individual and overall annual reports by every agency. Given the wealth of information available, and as we were on secondment to a government research centre, we felt that we should devote a large part of our work to analysing the trials conducted by the government; we wished particularly to focus our attention on the results of the Department of Communications' Office Communications Systems Program and the Treasury Board's Task Force on Informatics.

The Office Communications Systems Program was administered by the Department of Communications. It was launched to assist Canadian manufacturers of integrated electronic office systems and comprised two facets: research in various fields related to office automation, including productivity measurement, and field trials in certain government organizations with subsequent impact analysis, including productivity.

Both facets of the program generated many reports: research reports on theoretical or fundamental questions, given wide distribution through the Program Secretariat, and reports in connection with the field trials, distribution of which was restricted; an overall report on the trials was to be published in 1986. We had access to several of these reports and we made a careful study of all those that gave a general perspective and those that seemed related to productivity measurement. We also met with the authors of certain reports.

A detailed presentation of the Program from the standpoint of productivity measurement appears in the next chapter of this report.

The Task Force on Informatics was created in December 1982 by the Treasury Board Secretariat of the Government of Canada in order to review EDP concepts, practices, procedures, policies and structures in the government so as to develop a conceptual framework to ensure sound economic management [TASKF01]. The Task Force looked at various issues such as checking that investment and procurement decisions are made to achieve productivity gains and that the thrust toward office systems technology is managed with concern for problems in human resources management.

As part of its mandate, the Task Force conducted or commissioned several studies on technical aspects of informatics or on aspects related to EDP management, including productivity. These studies generated various reports some of which are distributed by the Treasury Board; they all carry the qualification, however, that they do not represent the Treasury Board's views nor have they been officially endorsed. We asked for and obtained some Treasury Board reports and gleaned further details from other sources; we found some interesting approaches in some of these reports.

One such report sets out a macroeconomic model of trends in various variables such as costs, labour and productivity (in terms of output per employee and output per dollar) in the federal government according to various scenarios from 1983 to 1993 [DPAGR01]; productivity is not expressed in absolute terms but changes are expressed in relative terms and both a quality and quantity component is assumed. It has also been proposed [MURRI01], in view of the needs of departments and the importance of productivity problems associated with informatics, that a consulting centre be set up to advise government agencies on the best ways of achieving productivity gains.

A full, detailed report [TASKF02] recommends guidelines for EDP planning in federal government agencies covering objectives, applications, data, technologies and management, including the human aspects. The

definition of informatics used includes networks and office automation. A structured Business Case approach has also been suggested [TASKF03] for cost/benfit analysis prior to the development of EDP systems; this proposal is illustrated by several examples.

As our information was not complete, and given that some of this information is confidential, we make no detailed discussion in this report of the Task Force's results.

3. DOC Office Communications Systems Program

3.1 Outline

The Office Communications Systems Program was administered by the Department of Communications. It was launched in 1980 by the federal government to assist Canadian businesses in theresearch, development, manufacture and marketing of integrated electronic office systems. It was realized that Canada was heading at that time toward a significant trade deficit in this field and that converting from traditional methods to modern technology would yield significant productivity gains in the ofice automation sector and would improve the competitiveness of Canadian firms [PROGB03].

Five pilot sites were identified within the government where specialized companies could install new integrated electronic office systems and conduct field trials. The various types of impact of these trials were also to be studied, including the impact on productivity. Independent firms not connected with the companies whose products were on trial were commissioned to carry out these impact assessments. Many reports were issued: research reports on theoretical or fundamental questions, given wide distribution by the Program Secretariat and reports on the field trials, the distribution of which was restricted. The Secretariat was to publish an overall report on these trials in 1986. We have studied several of these reports, focussing our analysis particularly on those offering an overall view and those that seemed related to productivity measurement.

The remainder of this chapter is devoted to a review of the main points that emerge from our analysis of these reports and discussions with some of the people involved. It comprises three sections: section 3.2 deals with some of the general results, section 3.3 outlines some potentially useful approaches for assessing productivity and section 3.4 is a synthesis of the Program's contribution to productivity measurement and to identifying certain lines of research in this field.

3.2 Some general results

3.2.1 Definition of office automation

The term "office automation" is much bandied about these days without precise definition; specialists attribute a whole range of meanings to it, from the very narrow sense of the "computerization of office work" to the much wider connotation of "the circulation and storage of information in organizations". Where does office automation stand in relation to information processing or information systems? Going by the narrow definition, office automation can be regarded as just another side of information processing; if it is taken in the wide sense, office automation can be considered a new field different from information processing and information systems or even encompassing both.

"Office automation" is often used as an umbrella term to cover various manifestations of technology applied to office work: word processing is the most obvious, electronic mail is another major application, as are time management and computerized archiving and tracking systems. In some of the OCS Program literature, reference is made to the "office of the future" [PROGB01] or to the technical, social, organizational or macroeconomic effects of office automation [PROGB02], but we were most surprised to find that no formal working definition of the term "office automation" had been adopted for the purposes of the Program.

Some research reports published under the Program throw some light on the subject, however. One of these reports [OFFIC01] presents an analysis of potential developments in microhardware and the kinds of strategies that Canadian hardware manufacturers could adopt to respond to these trends. This study is more useful for analysing market trends than technical developments in hardware and has little contribution to make to productivity measurement. It does, however, point up the many facets to this question. A similar perspective can be obtained from a good

bibliography on user manuals for office systems hardware [TOMBJ01]and from a report [DPAC001] which discusses possible trends in certain areas such as people and terminals in the federal government through 1992 based on three hypotheses and which illustrates the diversity of tasks and functions.

It would have been useful in our analysis of Program results to have a formal definition of office automation. Failing this, however, intuitively we have associated with it a set of activities related to document creation (such as word processing) and distribution, and communications in general (such as electronic mail), their storage and tracking (such as electronic archiving) and help in performing other activities (such as time management).

3.2.2 Productivity measurement

Several OCS Program reports deal with productivity measurement; the next section outlines some approaches we felt were interesting. Here, however, we wish to stress the contribution of other reports that illustrate the multi-faceted nature of the question.

A document [PROGB02] that seems to be an official statement of the objectives and main characteristics of the OCS Program gives various interesting information on productivity and on the value of information, including a productivity index based on the concept of value-added. A fundamental study on the various aspects of macro-productivity in national economies, and of micro-productivity in organizations, mainly from the economic standpoint [DALYD01], looks at productivity in relation to various kinds of information system models (Decision Support, Transaction Processing, Office Automation, etc.) and associated trends.

An interesting report [GRUST01] traces the introduction of two new machines in a coding and message transmission centre. From his standpoint as an independent observer, the author makes recommendations on how to ease

the introduction of new technology. The report contains data on production volumes before the introduction of the new machines and proposes that people productivity be monitored during the learning phase with an eye to measuring overall productivity after this phase.

A research project, the results of which were published at the end of 1982, examined in depth the social, organizational and human impacts of office automation [BOOTJ01]. The report tends to stress the negative impacts, such as greater control over employees, elimination of jobs and the lack of career advancement, and gives very useful information on the methodological aspects of measurement and some approaches, including "work teams" and "network analysis". It also refers to measurement activities conducted by certain groups. Another report [CECIT01] surveys articles on office automation and on associated models and methodolgies. It reviews a total of 34 works, classified in four groups (general works, works on modelling, works on methodolgies and related works), which are interesting for their usefulness in evaluating productivity.

A report on the impact of systems installed in one of the the field trials [BNRES01] presents data on system use by different users gathered from on-line monitoring, users' comments and a benefit analysis. Major benefits are reported, includingproductivity gains for managers and professionals. Quantitative gains, expressed as minutes saved per day, and qualitative gains, such as job satisfaction, were noted; the quantitative gains do not seem statistically significant to us, however.

Two reports [SILVI01] and [SILVI02] set out a conceptual framework for the cost/benefit evaluation of office automation systems. Their work is along very general lines that could be applied just as well to other types of systems. An interesting presentation is given on perceptions of office automation via three approaches to organizational theory: the classic (Weberian), organizational psychology, and systems theory approaches.

3.3 Some useful approaches

3.3.1 General

Our analysis of the OCS Program literature to which we had access did not yield models that could be easily applied in a different context from the one for which they were designed, or productivity indexes for office automation that seem statistically significant.

However, we did identify certain approaches of interest for modelling or measuring productivity, these are: "procedural activities" (T. Grusec), "present value" R. Engel and M. Townsend), "detailed analysis" (CECIT and Hickling Partners), "in-depth analysis" (F. Faulkner) and "baseline measures" (OCRA Communications). (The designations within quotation marks are our own; they seemed to us to be the most apt descriptions of the various approaches). These five approaches are outlined in the following five sections of this report.

3.3.2 Procedural activities

In the course of our search for useful approaches to productivity measurement in office automation, we examined two reports by Ted Grusec: one [GRUST01] synthesizing his observations as an independent observer during the introduction of two new machines to code and transmit documents in a telex centre, in which he made recommendations on facilitating such a process, and a second [GRUST02] which is an in-depth qualitative discussion of office automation productivity. As already mentioned, the first report contains certain data on production volumes before the new machines were introduced and proposes a way of evaluating productivity .

He makes some interesting points on productivity measurement in his second report: - according to available data, there is nothing to show that government offices are more or less productive than their private-sector counterparts; - investment in information technology may serve as an

amplifier of the financial state of a company for good or bad, i.e. it will pay dividends for an expanding firm, whereas it will make the problems of a struggling company worse; cost/benefit analyses of office automation should be comprehensive, taking into consideration a wide range of factors and functions.

As well as analysing these reports, we held discussions with Mr. Grusec. The gist of his approach would seem to be a two-fold classification of office activities: "procedural" activities consisting in the execution of a series of explicit steps to achieve a specific goal, and "non-procedural" activities which cannot be described in this fashion. Offices can be seen as "procedural", in which mainly procedural activities are carried out, and non-procedural; productivity in relation to procedural activities (and procedural offices) can be directly measured but the only way of measuring productivity in relation to non-procedural activities is to add them on as overhead to procedural activities.

3.3.3 Present value

G. R. Engel and V. M. Townsend were commissioned to assess the impact of the field trial conducted by Bell-Northern Research at Revenue Canada-Customs and Excise. Their report [ENER01] presents the broad lines of the trial, sets out the main impacts and describes a model of present value that can be used to evaluate productivity.

The trial consisted in making available to a hundred managers and professionals at Head Office in Ottawa and a regional office in Toronto integrated systems that automatically perform certain office tasks, such as word processing, electronic mail and time management. Use was voluntary; participants could use the systems or not, depending on how useful they found them to be for their work. Generally speaking, it was found that the number of users and the extent of use decreased over the course of the trial (January to August 1984), and that only a small number of

participants made substantial use of them. To us, therefore, Engel and Townsend's work seems to have been rendered somewhat difficult because of the small number of people effectively in the sample.

It was possible to perform a quantitative analysis for a small group of professionals already on an established work measurement system. The authors drew certain results from this analysis (increase then decrease in productivity), but we do not think that their conclusions can be statistically significant. In fact, they include three "vague" items in their calculations: 1) the definition of activities performed, which varied over the course of the study and for which aggregate expressions had to be used; 2) the use of averages for salary classes rather than averages or real values for the employees involved, and 3) the lack of actual prices for the equipment used, forcing the authors to estimate probable prices on the basis of the price of various equipment on the market. It seems that the combination of these vague factors may lead to greater variations than the changes observed in productivity. It would also have been very useful if the authors had specified the possible margin of error in their data and results.

The most favourable opinions were expressed by the heavy users while the least favourable comments came from participants who made least use of the system. It can be difficult to distinguish between cause and effect in this paradigm, but it seems that external factors, such as user motivation, influenced their opinions.

The authors did not find any way of measuring managerial productivity, and they state that any attempt to do so would be difficult, if not impossible, without a previous system to gather management information on their work. They made similar remarks on evaluating the productivity of professionals.

Engel and Townsend developed a small theoretical cost/benefit model which computes the present value of officesystems at different times consistent with certain hypotheses on trends in certain parameters, and analyses the sensitivity of the calculation of net gains to variations in these parameters. The report gives an example of the model applied to a specific case. The parameters used are:

- annual interest rate (IR)
- average user salary (US)
- annual rate of increase in workload (WI)
- annual rate of increase in costs (CI)
- number of workstations (NW)
- workstation cost (WC)
- operating cost (% of acquisition cost) (OC)
- percentage user productivity improvement (PI)
- workstation usage (WU)

The actual costs (AC) are obtained by multiplying the operating cost by the workstation cost by the the number of workstations:

$$AC = OC \times WC \times NW$$

Actual gains (AG) are computed by multiplying the average salary by the percentage productivity improvement by the number of workstations and by the usage rate:

$$AG = AS \times PI \times NW \times WU$$

Costs and benefits for subsequent years are obtained respectively by multiplying every year the actual costs (AC) and the actual gains (AG) by the interest rate (IR) and the rate of increase in the workload (WI). Annual net gains (NG) are obtained by subtracting actual costs from actual gains:

$$NG = AG - AC$$

Net present value (PV) is obtained by adding the capital investment required to acquire the workstations, the annual rate of interest and the net gains as derived from the model. The present value index (VI) can be calculated in similar fashion. Net gains (NG) can easily be calculated with different sets of parameters to show the sensitivity of calculation to variations in the parameters.

3.4 Detailed analysis

The University of Waterloo's Centre for the Evaluation of Computer and Information Technology (CECIT) and Hickling Partners designed an original model and methodology to analyse office systems, and their report (CECIT02) includes a section on economic evaluation, a glossary of definitions and a list of useful bibliographical references.

The model supposes that an office is a set of processes designed to transform inputs into outputs to accomplish a mission:

Inputs (information) — Process — Outputs (information)

The processes are organized hierarchically:

Mission — Functions — Tasks — Activities

Processes are considered to intercommunicate by transmitting information, and each process may also store information. Information, whether communicated or stored, possesses certain attributes such as its age, relevance for the process in question, frequency of production or the medium on which it is held. Attributes can also be assigned to processes, e.g., their cost, duration or importance.

Tasks, in the model, consist in pursuing general management objectives such as planning, budgeting or supervising staff, while

activities are performed as part of tasks: reading, observing, filing or calculating are examples of activities that can form part of various tasks.

More specifically, office applications are identified, such as telephony, electronic mail, text preparation or scheduling, with related tasks and activities, and technologies, such as a central computer, a terminal, a personal computer, a telecopier or a calculating machine, that can be used to perform applications. To help analysts in their work, two tables are given showing the possible relations between certain applications (e.g., scheduling) and the activities (organizing) and tasks for which they can be used and the technologies (e.g., personal computing system) through which each application can be performed (e.g. scheduling).

The authors indicate that it is often difficult to make precise economic evaluations in office systems because traditional cost models are designed around tangible assets and the objectives of office systems are geared toward intangible values. On the other hand, economic evaluations can be based partly on subjective judgments. The proposed evaluation method suggests performing as many cost/benefit calculations as possible and leaving decision making up to corporate senior management according to its own criteria.

The model is especially useful for analysis prior to the development and implementation of office systems, but it can also be used with some modifications for evaluating user productivity.There is a potential weakness, however, in that the authors appear to look on all system inputs and outputs as information very generally, making no distinction between data which are facts or raw observations and information which is the product of dataprocessing specifically destined for use in various functions,including decision making.

3.5.5 In-depth analysis

Fernande Faulkner of Socioscope was commissioned to assess the impact of the field trial of the Officesmith system at the Department of Energy, Mines and Resources, and the results of her work were published in a series of reports. We consulted the first on Issues and Lessons Learned [FAULF01] and the fourth on Analysis of Module Preparation [FAULF02]. We also met with Mrs. Faulkner.

For various reasons there were delays in the implementation of the system, so that it was not completely available to users when the impact assessment mandate expired. Unfortunately, her results are therefore mainly qualitative, and only measurements prior to implementation could be obtained from the method developed to evaluate productivity.

It is interesting to quote one of the author's comments: "What we observed was the 'crawling' phase of the technology - it was in place but faltering and we ended our study before it could be said to have been 'walking' on its own.

According to her comments to us, Mrs. Faulkner believes that it is possible to evaluate the productivity of people and processes in most organizations provided that enough time and effort are spent on analysing their component activities and on planning the approach to be used in evaluating them. Great importance must be given to the human aspects before and after the introduction of a new technology, because this is often the time to promote adjustment to change. On the other hand, delays and uncertainties in installing a system can lead to a decline in user motivation toward the system.

The Energy, Mines and Resources unit where the field trial took place was responsible for producing documentation modules. The number of initial users was limited (fewer than ten) and a staff reorganization took place at the same time as the system was installed. The approach developed for

productivity measurement consisted in tracking the progress of the modules through the various stages of production, noting various parameters such as the effort required at each stage, production and distribution times. Data was thus gathered on 17 modules, only four of which were completed during the author's mandate.

Productivity can be measured by comparing effort or time foreach stage with the number of pages created. Events and comments were also noted at each stage, enabling the measurements to be weighted by different factors, including complexity. The measurement model could be applied again once the system is completely in place to yield a comparison of productivity "before" and "after".

3.3.6 Baseline measures

OCRA Communications Inc. made an excellent fundamental study [OCRAC01] of the profile of participants in the field trial at Environment Canada. Data on five types of factors were gathered: general information (experience, training, demographics), working conditions (using a questionnaire from the Canada Labour Congress on the effects of CRTs), attitude to office technology (adaptation of a scale developed at Carleton University by Dudley and Tombaugh on attitudes towards computers), job diagnostic survey (measurement of job satisfaction using the Hackman and Oldham approach) and time diary (continuous record of people's activities.)

The sample comprised 78 participants and the overall response rate to the questionnaire and to most questions was very good (77 out of 78). The authors stress, however, that lack of time precluded interviews that would have allowed them to compile fuller information.

As it would seem from the version we consulted that the questionnaires were administered before the field trial only, the results report attitude prior to the trial rather than the impact on participants' work. People were found to be very motivated and receptive to computers.

From the scientific point of view, the authors of this report were careful to control all the variables in terms of their statistical significance. Responses to all items of the questionnaire on attitude towards computers were analysed and showed that three factors were at work:
1- emotional attitude (intimidation, frustration, fear, etc.),
2- professional attitude (impact of computers on work rather than on the individual) and 3- personal attitude (minus emotional overtones).

We feel that the OCRA approach described in this report can be used for impact measurement at various points in system installation, provided that control groups are set up to monitor all measurement-related factors.

3.4 Synthesis

The prime objective of the OCS Program was to help Canadian business develop new hardware and software products through field trials in certain federal government organizations. When the Program was launched, stress was laid on our trade deficit in this area and our low national productivity. Although we have a limited view of the results of the field trials, it is obvious that they allowed certain participating companies to make useful progress in the development of new products.

Implicit in the official Program literature but rarely explicitly expressed, the general idea was that the field trials would make for improved office productivity in the host organizations. An impact assessment was conducted on the trial in each host organization and the impact on productivity was to be one of the aspects studied.

In light of the information available to us, it would be presumptuous to claim that the work done under the OCS Program resulted in an increase (or decrease) in the internal productivity of the organizations in question. The few quantitative results in the reports consulted are either incomplete, having been obtained only before or after system installation, or non-significant because the samples were not large enough or the variables used were not closely enough defined. Some promising approaches for the future were identified, however, subject to proper controls.

Our tentative conclusions on our work so far are:

- it is difficult but not impossible to measure office automation productivity;
- certain prerequisites are necessary, as follows:
- office automation should not be isolated but regarded as a subset of a set of ways of providing the information required for decision making and carrying out other activities;

- these ways, which we term information processing, include data processing on mainframe computers or on micro-computers, telecommunications and various techniques related to the creation and storage of documents, such as word processing, electronic mail and archiving, normally grouped under the term "office automation";

- productivity measurement can only take place where a management information environment previously exists;

- various productivity evaluation models exist, but it is impossible to apply any model without an in-depth analysis of all its characteristics, especially the human aspects;

- users must be involved in developing the management information environment and in determining the conditions and characteristics of applying the productivity measurement model.

4. Summary of previous projects

We have been interested for several years in EDP management in general and in the impact assessment of computerization on organizations in particular. We thus conducted a survey of large organizations in the Montreal area into the mechanisms used in EDP planning; we also wished to measure how productively it is used and to gather the views of managers on these issues; the detailed results are given in another research report [ARDOP04] and a summary appears in Chapter 5 of this report. We have also developed a model to evaluate the costs and benefits of information systems in large organizations; a validation exercise was conducted on the systems of a large insurance company [ARDOP02], of which a summary is given in Chapter 6. Two of our other projects are outlined below.

In 1984, we co-operated in a research project on the impacts of computerization on the managers of small- and medium-sized businesses. Questionnaires were completed and individual interviews were held with the managers of several organizations in the manufacturing, finance and distribution sectors. The project covered various components of informatics such as conventional data processing, software, hardware, computer-aided design and manufacture, and office systems. The impacts studied were the effects on the organization, staff, other resources, training, human aspects, family life and productivity. Some of the project's results were presented at the 1985 conference of the Canadian Information Processing Society [ARDOP01], a summary of which is given below.

Computers are used in most small- and medium-sized businesses for accounting applications, such as invoicing, general ledger and payroll. The equipment used is typically a microcomputer or a minicomputer with two or three workstations. Applications in other areas such as sales analysis, production planning or inventory control depend on the complexity and

volume of operations associated with them. Productivity gains are generally perceived in terms of labour cost reductions following the introduction of computerized applications.

Among the impacts we observed, computerization results in time savings for most managers, increased control by managers over the work of their subordinates and increased control by the organization over the work of managers and in higher production standards; most managers also think that any EDP installation should be planned in detail in all its technical, financial and human aspects. We did not observe significant human impacts such as a decline in inter-personal relations between employees and managers.

Productivity gains through typical office applications, such as word processing, are fairly unlikely in most small businesses because most of them make limited use of formal communications compared with large companies. Potential time savings are to be found in the use of individual productivity tools such as spreadsheets and time management systems; we observed, however, that most managers of small businesses do not use such tools, mostly because they do not have the time to obtain information on their use.

Another project to which we contributed was the study of the strategies and effort required to develop EDP master plans [DROLJ01]. Such master plans are comprehensive, conceptual frameworks developed by large organizations for the effective and efficient management of all their EDP-related activities.

Typically, a master plan identifies the corporate objectives to be met by EDP, defines strategies and policies to achieve these objectives, and includes overall system architectures for data and technology with regard to applications. A master plan assumes the existence of a strategic plan for systems development and operation that is revised annually; the

strategic plan contains a detailed description of activities for the upcoming year, an outline of activities for the subsequent two years and identifies the resources to be used such as staff, equipment and budget.

A master plan also identifies the benefits expected from each system. Productivity gains are one such benefit and we feel that they should be explicitly expressed during the development phase and the productivity gauges to be used after installation should also be formally planned.

5. Information Processing Planning and Productivity

5.1 General

In early 1986, we surveyed over 50 large organizations to determine mechanisms used for information processing planning and productivity measurement [ARDOP04]. The survey enabled us to identify productivity measurements in use or being implemented, and to obtain the opinions of over 80 managers on various related topics, such as distinctions between information processing and office automation, the best means of measuring productivity, the role of users, expressing productivity in economic terms, and human impact.

We interpreted the term "information processing" to include data processing by computer, telematics and office automation, among other technologies, all of which are chiefly aimed at providing information for decision making. We did not wish to bias the survey or analysis of results by interpreting the term too narrowly, since some of our questions were designed to determine how managers distinguish between these technologies.

5.2 Sample

The survey involved 82 managers in 56 organizations, including 48 private firms and 8 government and para-public organizations. The average annual sales figure (or budget) was $475 million. Theaverage number of employees was 4,850 and the median 1,450. Questionnaires were filled out and interviews conducted with 15 EDP and 26 user managers, while 41 other EDP simply filled out the questionnaire.

Questions covered the organization (sales figure, number of employees), information processing (staff, total budget, and breakdown by certain categories of expenditure, including office automation), components for which formal planning is carried out, and components included in formal productivity measurements. In the interviews, we gathered managers' opinions about the distinction between information processing and office automation, methods of measuring productivity, expressing productivity in economic terms, the usefulness of measuring productivity, human impact, planning, the role of users and the use of results.

The majority of participating organizations had EDP operating budgets of several million dollars (between 1 and 5% of the sales figure) and from 50 to 100 EDP employees. Most sectors of these organizations were automated in some way, and many user managers made occasional use of information processing or office automation. Only half the organizations specifically identified office automation expenditures. These expenditures, in the order of $1 million, were almost exclusively for equipment.

5.3 Planning

We identified formal planning mechanisms now in use (or being implemented) for certain information processing components and for certain components associated with information processing; the questionnaire contained a list of 11 components, and respondents were asked to check off those for which official planning mechanisms were in use or being implemented. Formal planning refers to the preparation of plans that are valid for at least three years, and are approved and revised at least annually by senior management of the organization and by users.

Table 1 shows the breakdown of firms by planning mechanisms.

Components of information processing or associated with information processing	Number of organizations where planning is now either used of being implemented
Development of applications of information processing	51
Equipment (including networks)	49
Expenditures for information processing	44
Integration of computer-based systems	44
Personnel	43
Applications of office automation	40
Policies for management of information processing	39
Information required for the whole organization	36
Benefits of systems	36
Global data modelling	27
Measurement of productivity of users	24

Table 1 - Planning mechanisms in 56 organizations

Analysis of the above information indicates three categories. The first corresponds to traditional use of information processing, and includes components that must be planned out over several years: development of applications, equipment (including networks), personnel and information processing expenditures.

The second category (systems integration, EDP management policies, and benefits of systems) includes components for which planning must be carried out to prevent the kind of problems that usually occur when an organization develops and operates several systems. Fewer organizations formally plan for these components, because this means planning for a second generation of components. A third category comprises office automation applications, corporate information, global data modelling, and measurement of user productivity — all more recent concerns related to EDP management. Although these components merit consideration in many organizations, they are not significant enough to justify formal planning.

5.4 Productivity measurement

Our survey was intended to achieve a better overview of information processing productivity in general, and to determine how particular aspects of information processing were planned and what the main characteristics of productivity measurements in use were. The survey was also designed to identify mechanisms used to measure information processing and office automation productivity and obtain opinions of respondents on the distinction between these two terms. We could not therefore provide a definition without biasing answers. For similar reasons, we did not provide any definition of productivity, although we let it be assumed that it involves the relationship between certain "outputs" and certain "inputs".

We established a list of 13 components that could be used to measure productivity of users, and presented the list on two pages of the questionnaire, asking respondents to indicate information processing criteria on the first list and office automation criteria on the second. The results appear in Table 2.

Components used to measure user productivity	Number of organizations where mechanism is used for	
	information processing	office automation
Reduction in costs	28	24
Time savings by personnel	21	20
Efficiency of production	16	11
Effectiveness of production	16	12
Increase in revenues	15	12
Number of documents prepared by clerical support staff	14	19
Number of documents prepared by professionals	12	13
Number of documents prepared by managers	9	10
Quality of working life	9	10
Quality of managers' decisions	8	8
Employee motivation	8	12
Absenteeism	7	7
Quality of work of professional staff	6	9

Table 2 - Productivity measurement in 56 organizations

In most cases, the development of applications is economically justified through reduced costs. This explains why the method most commonly used to measure productivity is to see whether investment in a system actually results in a cost saving; another explanation is that it is easy to evaluate in tangible terms. The second most common measurement is that of time saved; time savings can sometimes easily be translated into reduced costs and have an impact on efficiency and effectiveness of production, the next two most common criteria. Several firms also measure increased revenues, or the number of documents produced by clerical and professional staff, but the importance of these components is somewhat limited.

In general, these mechanisms were more often used to measure information processing productivity than office automation productivity. The two most commonly applied criteria in both cases were cost reductions and time savings. The number of documents produced by clerical staff was used more often as a measurement of office automation productivity than of information processing productivity, mainly because word processing is a major element of office automation. Similarly, we can assume that personal computers play an important role in productivity of professionals, which explains the greater importance of this parameter as a measure of office automation productivity than of information processing productivity. The effectiveness and particularly the efficiency of the production of goods and services were more important as measures of information processing productivity, since office automation does not have as much to do with production. On the other hand, the human aspects, such as quality of working life and employee motivation, were more important in office automation, given the proximity of automated office equipment and users.

5.5 Opinions of respondents

One important objective of the survey was to get the opinion of managers on information processing planning and mechanisms used to measure productivity. Answers to our questions are summarized in the following paragraphs. The opinion questions were open-ended; participants freely stated their answers, which we noted down. Answers to each question were analysed as follows: we read all the answers, determined the general drift of each answer, and determined categories into which answers fell.

First, we asked all 82 participants what distinction(s) they made between information processing and office automation. The main distinction was in the diversity of functions performed by one or the other. Many managers felt that information processing functions were limited and that those of office automation were diversified, while others expressed the opposite impression! The "proximity" distinction was the second most frequent answer. It was mentioned by the majority of managers, reflecting the fact that information processing, at a distance from individual users, is used mainly to provide the entire organization with a service, while office automation can provide a personalized service closer to their needs. Another distinction was "authority". Nearly all managers were under the impression that information processing was the responsibility of senior management or of specialists, while office automation was the responsibility of users.

Distinctions were made according to "equipment", "volume of data processed" and "software", but these were not expressed by a large number of managers and were sometimes the subject of contradictory opinions. Several managers also indicated that they made no distinction between information processing and office automation.

A summary of answers to the question on best ways to measure productivity of information processing and office automation users appears below. Since respondents did not indicate any significant difference between the two, we did not distinguish between them in Table 3.

Answer category	Number of managers by answer category (max = 41)
Quality of output	22
Time savings	19
Quantity of output	16
Cost reduction	14
Human benefit	10

Table 3 - Best productivity measurements

In Table 3, "output" corresponds to the production of users working with information processing or office automation systems, while "human benefits" include customer satisfaction, employee motivation and development of new tasks. The table shows that most managers felt that the best way to measure productivity was to measure quality of work performed by users; this is difficult, however, as many respondents pointed out. Cost reduction, time savings and quantity of output were considered to be important measurements by the majority of managers, and the results in this area were comparable with those for measurement mechanisms actually used in organizations.

We also asked respondents whether they felt that an expression in economic terms (costs and benefits) was a correct representation of user productivity. A majority of respondents, 27 of 41, answered yes to this question; some, however, added that although one may easily measure costs, there are qualitative benefits that can only be measured with great difficulty. Similar arguments were also used to justify most of the negative answers.

There was a question on the usefulness of measuring user productivity, and another on the need for formal planning of criteria. Answers to both questions appear in Table 4.

Answer categories	Number of managers by answer category	
	Usefulness of measurement	Need for planning
Yes	24	17
Yes, with restrictions	13	11
No, or other answer	4	13

Table 4 - Usefulness and planning of productivity measurement, for 41 managers

Most respondents felt that productivity measurement was useful, mainly to check whether investment had been worthwhile, that is, whether expected reductions in expenditures or increases in revenues had actually come about; this was in line with the importance ascribed to reduction in expenditures among productivity criteria actually in use. Many managers mentioned reasons other than economic ones for measuring productivity, such as verifying whether users were properly trained, whether equipment was being used correctly, determining the human or organizational impact of systems, and comparing the performance of various sectors within an organization, or of an organization in relation to its competition.

Most managers felt that measurement should be formally planned. There is, however, a certain contradiction between this majority opinion and the actual situation reported in organizations; very few actually planned formally for productivity measurement. Perhaps the managers we spoke to were more avant-garde than the organizations they represented, and will soon be helping to establish such mechanisms.

Some managers saw no need for formal planning, feeling that a system must be introduced before productivity could be measured, or that a master plan must contain strategic objectives or organizational policies for implementation, and that productivity criteria are too specific to be included in such a plan. Respondents almost unanimously agreed that users should have considerable responsibility for determining productivity criteria.

The last question, answers to which are summarized in Table 5, concerned the human impact of implementing systems for measuring productivity. It was formulated as follows: "Do you think that the sole fact of measuring user productivity might result in a productivity increase? ...in a productivity decrease?"

Answer category	Nb. of managers by answer category
Temporary or partial increase	13
Practically no effect	12
Increase because of greater awareness	10
Mention of stress, fear, psychological effects	9
Decrease (sometimes temporary)	4
Mention of union opposition	2
Increase, but decreased quality	2

Table 5 - Human impact of productivity measurement according to 41 managers

We had thought that the human impact of introducing productivity measurement (mentioned by nine of the managers with whom we met) would result in decreased productivity in most cases. The answers show that a majority of managers perceive positive effects on productivity. Only two respondents said that productivity would decrease because of union opposition.

5.6 Observations

Many observations may be drawn from the survey. However, certain trends corresponding to main answer categories stand out. Interested readers will find each observation presented and justified in [ARDOP04].

It seems that it is possible, although sometimes difficult, to measure productivity in most areas of information processing. As the objective of most investment in new technology is to increase user productivity, the only way to measure the attainment of objectives is to measure productivity, however difficult this may be.

The main types of mechanisms used to measure productivity fall into two categories. A general category, which includes reduction of expenditures and time saved, is used to evaluate both information processing and office automation productivity. Mechanisms specific to each are efficiency and effectiveness of production for information processing, and the number of characteristic tasks performed by clerical support staff and professional staff, respectively, for office automation.

There are other ways of expressing productivity, but only an expression in economic terms, such as a cost/benefit ratio, may incorporate other forms of expression and results from different sectors. Human aspects, such as quality of working life and employee motivation, and other benefits that are difficult to quantify, may be used as subjective weighting factors in making decisions based on productivity measurement about such matters as investment.

No significant distinctions are made between office automation and information processing, and for purposes of measuring user productivity, office automation should not be isolated from other convergent technologies to which we refer as "information processing"; these technologies sometimes use similar tools and are designed to achieve similar objectives.

Whatever the mechanisms employed to measure user productivity, it is not possible to apply any method until all technical, human and organizational conditions and characteristics of its application have been formally planned; in addition, given the relationship between sectors of an organization and employees in each sector, mechanisms should generally be applied in all (or several) sectors.

Finally, in the formal planning of productivity measurement, users should play an important role, assuming final responsibility in most cases.

6. Cost/benefit model

6.1 General

We developed a cost/benefit model for information systems in large organizations [ARDOP02] as part of a project to devise an operating model of a company, based on exchanges of information among its component parts, so as to identify parameters through which the value of processed information can be maximized locally and globally.

The model sees an organization as a set of components linked by formal and informal channels of communication. We define aninformation system as a collection of hardware and software elements and procedures applicable to some or all components, that supplies information for decision making and in support of other activities in some or all components. The main functions of any system in any component are the storage and processing of data, which can be performed by various technologies.

Costs are incurred in operating any system in any component, especially with regard to personnel and equipment, whatever technology is used. Adding up the costs in all the components gives the total cost of the system; this can be calculated for some or all time frames. Unit rates can be used to measure each cost in every component, with measurement being the responsibility of a central component of the organization.

Any system may yield two types of benefit in any component: tangible benefits, mainly associated with time savings by different classes of employees and easily expressible in monetary terms by means of unit rates, such as hourly pay rates, and intangible benefits, such as better executive decision making or increased employee motivation. Intangible benefits are difficult to measure and express in monetary terms, but they can sometimes be assessed indirectly: for example, executives can estimate what they

would be prepared to pay out of their own budgets to obtain the information used if it was not supplied by the systems. The sum of benefits in all components can be calculated for different time frames.

The net benefits of a system are the difference between the overall (gross) benefits and the total cost, and the net benefit/cost ratio gives the company's rate of return on investment in the system. The ratio can be used as a corporate economic productivity indicator.

To test the model a validation exercise was run on all the systems of a major Canadian financial institution and some points were also tested in some French companies.

6.2 Some mathematical aspects

An organization is taken to have **n** components (departments, divisions, etc.) and **m** information systems (personnel, accounting, sales, etc.). The main functions of the systems are represented by mathematical functions, whereas the data involved are variables processed by these functions. For any system in any component there are two classes of functions (storage and processing) and three sets of data (received, stored and produced). The model assumes that systems operate on a periodic basis (weekly, monthly, etc.). It is not possible to give a detailed mathematical presentation here.

Given system **i** (personnel management, for instance) and component **j** (any department) and a time frame between **t** and **t+Dt**, the model assumes that the system can be represented by equations by which stored data at the end of the period and results produced during the period can be calculated on the basis of operations on the data stored at the start of the period and received during the period.

In any system, executing operations entails costs for storage and processing in some or all of the components. Costs can be assessed through parameters such as person-hours or computer time, to which unit rates can be assigned. Benefits can generated in some or all of the components. There are tangible benefits that correspond mainly to savings generated by the computerization of certain activities and intangible benefits stemming mainly from better decision making as a result of the information received.

Equation (1) shows the computation of the costs of system **i** in component **j** during the time frame **t** to **t+Dt** by adding the storage and processing costs; these costs can also be obtained by summing non-EDP and EDP costs.

$$c_{ij_{t+Dt}} = cy_{ij_{t+Dt}} + cz_{ij_{t+Dt}} \quad (1)$$

where $c_{ij_{t+Dt}}$ represents the costs of system i to component j during period

$cy_{ij_{t+DT}}$ storage costs and $cz_{ij_{t+Dt}}$ processing costs.

Equation (1) can be summed for all j components (j= 1,2,.....n) to obtain the total costs of system i throughout the organization for the period in question.

$$c_{i_{t+Dt}} = \sum_{j=1}^{n} c_{ij_{t+Dt}} \quad (2)$$

Equation (3) shows how benefits are calculated for system i to component k by summing the tangible and the intangible benefits.

$$e_{ik_{t+Dt}} = et_{ik_{t+Dt}} + ei_{ik_{t+Dt}} \quad (3)$$

where $e_{ik_{t+Dt}}$ are the benefits of system i to component k during the period

$et_{ik_{t+Dt}}$ the tangible benefits and $ei_{ik_{t+Dt}}$ the intangible benefits

Equation (3) can be summed for all components k (k= 1, 2...n) to obtain the total benefits of system i during the period.

$$e_{i_{t+Dt}} = \sum_{k=1}^{n} e_{ik_{t+Dt}} \quad (4)$$

The difference between total benefits and total costs gives the net benefits of system i during the period.

$$v_{i_{t+Dt}} = e_{i_{t+Dt}} - c_{i_{t+Dt}} \quad (5)$$

The ratio of net benefit to cost can be calculated to obtain an organizational productivity measure related to system use; this ratio is the economic performance index.

$$r_{i_{t+Dt}} = v_{i_{t+Dt}} / c_{i_{t+Dt}} \qquad (6)$$

Costs and benefits can be summed over several periods to obtain the net benefits and the economic performance index for a longer time frame such as a year.

6.3 Example

The model was evaluated last year in a large insurance company, Industrial, which has its head office in Quebec City and branches in several provinces. The company has over 2,000 employees, over 700,000 customers, annual revenue of $300 million and insurance coverage of over $12 billion. The evaluation covered 30 components of the company.

We identified 11 information systems: records, general insurance, group life insurance, individual life insurance, accounting, mortgages, payroll, sales staff, investments, group annuities and individual annuities. Most of the systems are on-line. Some systems run on outside service suppliers' computers. Some systems store data on microfiche. Microcomputers are used for stand-alone applications or intermediate processing. Office applications include word processing and limited electronic mail.

We used three ways of collecting data for validation purposes: a questionnaire given to all managers, meetings with chief users and discussions with EDP managers. The information obtained was based in most cases on 12 one-month periods. Table 6 summarizes the costs and benefits in all components; the net value is the difference between total benefits and total costs.

System	Costs			Benefits			Net Value
	Users	EDP	Total	Tangible	Intangible	Total	
Sales staff	179	353	532	5672	885	6557	6025
Accounting	509	96	605	3946	927	4873	4268
Individual life ins.	466	2316	2782	3812	1385	5197	2415
Group life ins.	429	1052	1481	2185	1103	3288	1807
Individual annuities	197	134	331	683	288	971	640
Mortgages	158	318	476	996	65	1061	585
General insurance	35	716	751	995	278	1273	522
Investments	99	0	99	401	183	584	485
Payroll	263	82	345	504	124	628	283
Group annuities	319	28	347	368	175	543	196
Records	946	10	956	162	80	242	-714
Total	3600	5105	8705	19724	5493	25217	16512

Table 6- System costs and benefits (in $ thousands)

The costs and benefits shown in Table 6 are absolute amounts; they are sizable and significant, but comparing relativebenefits to costs throws a different light on them. This gives a performance ratio in terms of net benefit or net value over total costs. Table 7 shows these performance ratios or productivity indicators.

System	Total costs	Total benefits	Net value	Performance ratio
Sales staff	532	6557	6025	11,33
Accounting	605	4873	4268	7,05
Investments	99	584	485	4,90
Individual annuities	331	971	640	1,93
Mortgages	476	1061	585	1,23
Group life insurance	1481	3288	1807	1,22
Individual life ins.	2782	5197	2415	0,87
Payroll	345	628	283	0,82
General insurance	751	1273	522	0,70
Group annuities	347	543	196	0,56
Records	956	242	-714	-0,75
Total	8705	25217	16512	1,90

Table 7 - Performance ratios (costs and benefits in $ thousands)

Several systems have a high ratio and the overall ratio is 1.90, which corresponds in financial terms to an annual net rate of return on investment of 190%. The EDP effort of this company is therefore highly cost-effective. Only one system - records - had a negative ratio and it was under review during the validation period.

We asked the managers to express the intangible benefits in monetary terms by evaluating the information generated by each system, which gives a measure of the use made of the information in decision making. We noted that several managers do not use this information for their decision making; we think that there are two possible explanations for this phenomenon. The first is that several systems were designed for

transaction processing at the operational level and do not provide useful information for decision making; the second is that managers through lack of knowledge or fear of computer technology are not open to the use of system results in their decision making. We feel that these explanations would be valid for other organizations too.

6.4 Accuracy

Calculating the above performance ratios involves four types of measurement: EDP costs, non-EDP costs, tangible benefits and intangible benefits. The measurement of EDP costs was relatively accurate because there were mechanisms for gathering this data. Non-EDP cost measurement, mainly employee time, is probably no better than 10% accurate, because there was no systematic procedure for gathering this data.

To evaluate the tangible benefits, the managers estimated the staff required to manually perform the work done automatically by each system. This was generally a fairly difficult estimate to make, because there was no basis for calculation or because it would often have been impossible to do the work manually. This measure is probably no better than 25% accurate. For the intangible benefits, the managers estimated what they would be prepared to pay for the information received, consistent with their needs, if it was not provided automatically; this estimate was not very accurate. Thus, the model, as applied, does not seem to yield good enough results to draw any strict conclusions.

To produce better results and improve the model's usefulness, we recently conducted a study in three major French organizations (to be reported on soon in a research study from Laval University). We sought the views of user managers on how possible they felt it was to evaluate the tangible and intangible benefits but rather than asking them to evaluate after the fact the savings in manpower and the value of the information we asked them to estimate the tangible and intangible benefits in terms of certain decision scenarios; most of the managers responded within an acceptable degree of accuracy. We think that incorporating such an approach into the model would yield more accurate results.

6.5 Summary

We feel that our MIS cost/benefit model can be usefully applied, provided that certain prerequisites are met. To obtain accurate measurements of EDP and non-EDP costs systematic data gathering mechanisms on cost components have to be set up. Furthermore, to accurately evaluate tangible or intangible benefits requires a prior estimate and at least an annual review of the nature and monetary value of the expected benefits from each system, along with evaluation mechanisms; it also requires that this evaluation be done periodically by managers with respect to concrete situations with which they are familiar.

The very broad definition given to information systems means that the model is not applicable just to traditional management systems but can also be used to study changes in productivity and other impacts resulting from the introduction of various types of new technology, including office systems. We feel, nevertheless, that there will always be a subjective aspect to the model and to any subsequent use of its results.

7. Review of the scientific literature

7.1 General

Various models exist to study the impacts of computerizationat the macroeconomic level (import/export, unemployment, balance of payments, etc.) or at the basic microeconomic level (customer service, word processing, etc). Even if many scientific articles have been written on the subject (see the extensive bibliography at the end of this report) there are few models that have effectively been applied to the analysis of user productivity within organizations or components of organizations.

The simplest method to measure the impact of technologicalchange on user productivity is to calculate the time required to do a certain number of repetitive well-defined tasks before and after the introduction of a new technology; changes in the time required give an asessment of changes in productivity. A typical situation where this method can be used is the study of productivity gains in a typing pool when conventional typewriters are replaced by word processors.

In most cases, however, the work users do is characterized by various kinds of activities, only a few of which qualify as repetitive well-defined tasks, whereas others vary in nature and duration, so that the impact of technological change on productivity is more difficult to measure. For example, a secretary in an office normally performs other tasks such as answering the telephone, looking up information or filing documents, as well as typing, and the net outcome of replacing a typewriter by a word processor can be difficult to measure. Moreover, the typing load can fluctuate in nature and duration over time, complicating the estimation of changes in productivity. In such cases, it is sometimes possible to considerthe effort required to perform non-repetitive tasks as overhead on the effort required for the repetitive tasks that are measured for productivity assessment.

Organizations are complex networks of interrelated components; technological change in a component can result in changes in productivity in other components. To be accurate, productivity changes related to technological change must be measured in various components. For example, when a secretary improves her productivity typing, this should normally be reflected in the productivity of the professionals or managers who generated the documents to be typed; changes in the productivity of service units such as Personnel and Finance would be worthless without a corresponding impact on the mainline departments.

Technological change that produces changes in productivity generally results in an increase in costs (such as the acquisition cost of word processors). An economic expression of productivity changes (such as the time savings of a secretary expressed in money by means of an hourly pay rate) allows for direct comparison with associated costs. Several techniques such as the computation of value-added by the technology or of the present value of the technology are useful for the cost/benefit analysis of productivity changes.

The remainder of this chapter discusses the main characteristics of certain approaches that emerged from our review of the literature from the standpoint of productivity measurement in general and as an indicator in terms of impact measurement of the value of information for decision making.

7.2 Productivity measurement and other impacts

To simplify matters, we use the term "information processing" to refer to a collection of convergent technologies, including electronic data processing, telematics and office automation systems, one of the objectives of which is to provide information for decision making; such an approach assimilates traditional information systems and information centres to these new technologies. Other manifestations of information technology are computer-aided design and manufacture, and home computing on microcomputers. How can the impact of information technology bemeasured, including the impact on productivity and other effects?

New technology impacts on society, organizations and individuals. Following a critical analysis of work from various sources [ARDOP05] we concluded that it is possible to measure impact at all levels, subject to various constraints. The social impact is difficult to measure as political factors come into play; at the human level, psychological and cultural factors must be taken into account. Organizational impact is easier to measure; through it the impact on the particular sector the organizations belong to and the individuals working in them can be studied. Some recent studies, the findings of which we looked at, are relevant here.

Various studies were conducted by the Diebold Group in the United States; the Group publishes a periodical [DIEB003] which gives references on various subjects related to productivity associated with the use of new technologies and grouped under various sub-headings including the automation of production and the economic environment. Another published study [DIEB001] found that increased user productivity is the main objective for systems development in the eighties and that emphasis should be laid on the development of computerized decision support systems to assist the human decision-making process.

The Diebold Group also prepared guidelines for the management of office automation applications [DIEB004]. Three important areas were identified in organizations: information systems, office systems and telecommunications; and given the trend, emphasis was laid on office systems. The report proposes that management should see office systems as two classes of functions, applications and resources, and that someone be made responsible for each class. Ten typical office applications aredescribed in detail and four basic principles for the effective management of office systems are given: 1- the development of applications that will increase the profitability of the company; 2- the involvement of users in the entire process; 3- full support service for users; 4- co-ordination and centralized planning.

Another document published by the Diebold Group [DIEB002] gives the results of a survey of 500 large organizations in the USA and Canada on the nature, extent (in 1983 and in 1985) and impact of office automation on four categories of employees: support staff, professionals, middle managers and senior executives. These results show an increase in the number of workstations between 1983 and 1985, an increase in use in general, but a smaller increase among professionals and senior executivesthan in the other categories. No precise details are given on how many people did in fact respond and the results are presented as a frequency breakdown (e.g., the percentage of respondents who noticed an increase in use) rather than in absolute terms (extent of use). The results are therefore more useful for the qualitative aspects rather than the quantitative aspects. This is an important study whose value should not be minimized.

For some years the Massachussetts Institute of Technology Center for Information Systems Research under the direction of Professor John F. Rockhart [ROCKJ01] has been proposing a so-called critical success factor approach to activity management in various areas; this approach supposes that among the various areas of activity for which a manager is responsible, there are some for which favourable results are crucial to the

achievement of the manager's objectives. For example, for an EDP manager, such factors might be: 1- service to users and the company, 2- communication with users and senior authorities, 3- EDP staff, 4- the corporate view of EDP. Critical success factors vary with people and companies, and good managers develop sets of management tools, techniques and processes to obtain good performances in these critical activities. With this approach the ideal management characteristics of EDP activity can be identified.

The Corporate Productivity Research Group of Toronto proposes a supposedly infallible method to measure productivity in practically all areas of all businesses [CPRGR01]. This method views productivity as multidimensional and as requiring a strategic approach and multidisciplinary perspective in order to measure it. Productivity can be gauged by measures such as employee output per hour of work, and by pseudo-measures such as absenteeism. This method calls on different concepts such as the spiritual dimensions of organizational life and critical success factors. We are not convinced that this approach would pinpoint the EDP-related component of organizational productivity.

The National Productivity Institute was a non-profit agency funded by the Quebec government to promote exchange, inform the community and economic agents, and to recommend productivity measures. The Institute published a general-interest periodical ("Productividées") and the results of various studies. One of these studies concerned the definition of the concept of productivity [INPR001]; generally speaking, productivity is to be found at various levels (individual, group) and includes indirect aspects. Essentially, productivity can be defined as a ratio of production to resources. Production, in principle, has to be defined in physical terms (goods or services produced); resources cover capital investment, labour, raw materials, intermediate consumption, energy and so on and have to be expressed in units of measurement that can be computed and are compatible with production to have a valid relationship. This report also stresses that productivity measurement is a difficult task.

A very interesting concept to promote employee participationin the various facets of the life of an organization is the "quality circle"; the Toronto Dominion Bank's experimental program described in Bank Notes [TORODO1] is a good example. The program was introduced in a number of branches and basically consists in weekly meetings of eight to ten persons to discuss and find solutions to problems affecting their branch. Mechanisms have been put in place for interaction with management. In general, the objective of any quality circle program is to improve the quality of work of employees so that their productivity increases.

Almost ten years separate two major studies on the relationship between new technology and the overall productivity of a country: the study by S. Nora and A. Minc in 1978 on technology and its socio-economic impact [NORAS01] which made recommendations, mainly of a political or economic nature, to the French government to control the development of technology, and the paper produced by P. Strassman in 1985 on the impact of information technology on the US economy and the world of work and on organizational productivity characterized in economic terms of effectiveness, efficiency, value-added and profitability [STRAP01].

In 1983, Professor G. Wybouw of the University of Moncton [WYBOG01] analysed trends in information processing and its sectoral impact on employment in Atlantic Canada. His report gives a summary of contemporary thinking on the impact of new technology on employment in general and also sketches a picture of employment in the Maritimes. Trends are analysed over several years in 15 economic sectors using linear regression models to forecast trends in each sector. The report also includes three detailed case studies (Acadian caisses populaires, an insurance firm and a food store chain) in which actual employment trends are compared with a non-computerized scenario. The method of analysis is interesting and could be applied to other larger or smaller sectors, subject to the availability of data and the ability to identify where technological change has occurred.

7.3 Value of information

In order to verify the potential of using an economic approach to measure productivity and other impacts of computerization and especially the potential of putting this information to use by decision makers to express the intangible benefits of systems, we consulted the work of some economists.

Thus, we read former Nobel prize winner Kenneth J. Arrow. Some of his work [ARROK01] [ARROK02] bears particularly on classic economic approaches to cost minimization and profit maximization, making only summary mention of the usefulness of information in decision making on resource allocation. One book [ARROK03] is significant for the study of the costs and benefits of information; it supposes that one of the difficulties of a costing system being uncertainty, having an information system is therefore very useful for reducing uncertainty. Costs are associated with installing and using systems: they involve spending on different types of resources (human, material); some of these expenditures are operating costs whereas others are capital costs; costs are not uniform in all directions. No synthesis of costs versus benefits is given but there is a discussion of guidelines for decision making (responsibility, authority, etc.) consistent with cost considerations.

Another celebrated economist is Jacob Marschak. In 1969, he put forward the basis of an economic theory of information for decision making [MARSJ01]. He successively explores decision making with full information available, in a context of uncertainty as to events and data, then requests with and without noise*. Each of these concepts is expressed formally in mathematical terms. There exist decision, cost and benefit functions and the gross and net benefits of certain actions can be calculated, given certain events. The probability of events must also be taken into account. In another text in 1971 [MARSJ02], Marschak discusses the "information revolution", one of the characteristics of which is the existence of communication chains, comprising various services such as

coding, transmission and decoding. These services are performed by human and material resources with which costs are associated; the value of services depends on their capacity to increase the probability of good decisions and there are various approaches (Bayesian, non-Bayesian) to analyse costs and value.

In pursuing his vast work in macroeconomics on the production and distribution of knowledge, Fritz Machlup assembled a collection of articles by over 50 researchers in 30 disciplines in 1983 (unfortunately he died before his book was published). The purpose of this book [MACHF01] was to collate all the views of specialists with different backgrounds all interested in information as the crossroads of all these various disciplines. It makes the point that information can be studied from various standpoints and that its definition can have widely divergent meanings even if the same words are used. In an epilogue to this book (unfinished at Machlup's death and completed by U. Mansfield) [MACHF02], Machlup comments on the etymological meaning of the word "information" and discusses various viewpoints from which it can be defined. He points out that one of the characteristics of information is to reduce uncertainty in deciding on a course of action, but stresses that 90% of all information received is not related to decision making or actions to be accomplished.

A book by Harvard University professors R. N. Anthony and R. Herzlinger [ANTHR01] deals with the management of a non-profit organizations in a fairly comprehensive way as it covers a large spectrum of organizations and looks at many of the management problems that can arise in them. As well as a description of non-profit and profit-oriented organizations and an analysis of their similarities and differences, it contains a discussion of the classification of revenue and expenditures, the inputs and outputs of the management process, programming and budgeting, the systems that underpin an organization's operations, information and its role, and the characteristics of sound management. The chief message would seem to be that most aspects of the operations of a non-profit organization can be managed in the same way and on the same

principles as profit-oriented organizations, including the detailed calculation of costs and, with certain limits, the expression in economic terms of certain benefits. This is a work of great value in support of the introduction of an economic model of organizational productivity related to information processing in any kind of organization.

Several other authors, in addition to those mentioned above, have used the concept of the value of information in estimating the benefits of computer systems. A. M. McDonough in 1963 was the first to put forward the concept of the economics of information, J. C. Emery in 1971 proposed a probability-theory approach to evaluating information, and G. A. Feltham in 1972 integrated various concepts into a detailed mathematical model. In a series of recent articles [CARTM01] [CARTM02], M. P. Carter endorsed the work of these classic authors, pointing out that their views are still valid today and that the value of information can be used to measure system benefits.

Although we were convinced of the potential of an economic approach to measure productivity and other impacts of computerization, based on a comparison of the benefits derived from information technology and the capital costs, we wished to verify whether there were other approaches used in other sectors that could be applicable to us. We thought that in the world of advertising there was surely a way to compare the extra revenue generated by an advertising campaign with the costs of the campaign. We were surprised and disappointed to find that according to numerous analyses by various authors the mathematical models used to relate sales revenue to advertising costs produced results that were too incompatible with each other to allow valid conclusions to be drawn on the parameters of such links [POLLR01]. Prudence is therefore called for in applying such an approach to productivity measurement in relation to information processing; it should only used when all the conditions have been carefully planned for.

8. Economic approach to productivity and impact measurement

8.1 General

Before presenting the guiding principles of the economic approach we propose, we wish to review certain important points mentioned in previous chapters.

We have used the term "information processing" to mean a set of convergent technologies, including electronic data processing, telematics and office automation systems, one of the objectives of which is to supply information for decision making by assimilating traditional information systems and information centres to information processing, as is also the case for computer-aided design and manufacture and home computing.

Although the federal Office Communications Systems Program does not seem to have produced significant results for productivity measurement, nevertheless it did bring forward models and approaches that can be used in this field; we noted the concept of procedural and non-procedural activities, the model of present value, and the idea that in-depth studies and baseline measures are prerequisites for productivity measurement.

We conducted a survey on EDP planning and how productively it was used in over 50 large organizations to identify the mechanisms used or planned to measure productivity. Through this survey we gathered the views of over 80 managers. The results show that there are two major classes of productivity criteria used in organizations. The first applies to all areas and comprises such tangible measures as cost reductions and timesavings and the second is sector-dependent and covers the effectiveness and efficiency of production of goods and services. The managers' views demonstrated that it is difficult to distinguish between information processing and office automation,that a representation in economic terms is a good way to express productivity and that users should play a major role in determining the criteria to be used for productivity measurement.

We developed a general model to analyse the costs and benefits of information systems that takes account of information processing costs and user costs and tangible and intangible benefits, the value of information being used to express the intangible benefits. This model can produce a set of economic productivity indicators for systems individually and collectively,with no restrictions on the type of technology used in each system. The model was validated in an exercise that applied it to all the systems in a large organization.

We also researched the scientific literature and noted that there was considerable material on productivity measurement. This research showed that measurement is possible but that in any given context the method must be chosen with great care, that organizational productivity can be characterized in economic terms of effectiveness, efficiency, value-added and profitability, and that the value of information can be used as a partial indicator of system benefits.

Following a critical analysis of the findings of these various sources, we concluded that it is possible to measure impact at all levels, subject to various constraints, however. Measurement at the level of society is complex, involving political factors; at the human level, psychological and cultural factors come into play. Measurement is easier at the organizational level and impacts can be assessed on the segment of society to which organizations belong and on the people in that segment. Furthermore, even if impacts vary in nature, expressing them in economic terms makes quantitative study easier. This was our line of thinking in laying the groundwork for an economic approach to impact measurement of new technology on organizations and especially on the productivity of EDP users.

8.2 Master plans

The economic approach we propose is in keeping with the EDP master plan concept. Before describing the main lines of our approach, we wish to discuss some of the characteristics of master plans referred to in a previous chapter as the formal frameworks for the effective and efficient management of all EDP activity. We analysed these plans and the role that user managers have to play in their development [DROLJ01].

Generally speaking, a master plan identifies corporate EDPobjectives, defines policies and strategies to achieve them and includes the global architecture of applications, data and technologies. It is accompanied by a comprehensive systems development and operation plan covering at least three years and revised annually by senior management and the users involved, encompassing all the resources required (human, material, software, budgetary) and all EDP activities. Developing such a plan requires wide-ranging managerial input. It is a dynamic (sometimes iterative) process, in which various elements must be considered in sequence, such as the current situation with regard to data, processing, technology and the organization, summed up in light of its orientations and objectives. A strategy for information systems, a target situation and a transition plan can be drawn up and the ensuing costs and benefits calculated.

Although a master plan is a multi-year document, its component parts can be revised from time to time: policies and strategies can change as a result of changes in the orientations or objectives of the organization; the architecture of applications, data and technologies can also change, particularly in the course of development; the overall plan should be revised at least annually as part of the budgetary process. Master plan updates call for co-operative structures such as a steering committee or working groups.

8.3 Guiding principles of the proposed approach

The approach we propose is based on a set of guiding principles which are detailed below and illustrated by examples (the mechanisms and means used in practice may vary with the individual characteristics of each organization, however, and are not given in detail):

I) Given the effort required to measure impact, it is essential that the objectives first be identified to determine whether the expected benefits justify the cost.

For example, a detailed study would not be justified to measure the impact of acquiring a word processor, but it would be important when installing an integrated office systems network throughout an organization.

II) Users should be responsible for planning the mechanisms to be used in all sectors in which the technologies are to be introduced, the master plan being the ideal framework for this planning.

Thus, during the installation of an integrated office systems network, managers in all sectors should identify productivity objectives to be achieved in their sector and the mechanisms to be used to verify this.

III) Although there are various kinds of impacts, and they can occur at various levels, there are general criteria to measure them in all sectors, such as cost and time savings, and criteria that vary with the various sectors such as the efficiency and effectiveness of production lines.

The introduction of an electronic mail system could yield time savings throughout an organization and improve efficiency in areas such as a supply department which makes considerable use of the organization's internal communications system.

IV) Measurement results can be expressed in different ways, but only by expressing them in economic terms can other forms of expression and results from different sectors be integrated and benefits directly compared with costs. Calculating economic indicators is particularly useful for this. The human aspects and other benefits that are hard to quantify can be used to clarify decisions based on economic considerations.

For example, time savings in all sectors, and improved effectiveness in a supply department could be translated into monetary terms and compared with the costs of anelectronic mail system; less tangible factors such as employee motivation or user satisfaction could come into play in analysing the economic productivity ratio whendeciding whether to modify the system.

V) For the purposes of impact assessment, the differences between technologies such as electronic data processing, office automation systems, personal computing or telematics are not always significant and they should not be considered in isolation from each other. A system can be broken down into sub-systems, however, and their economic indicators calculated independently.

For example, the functions of an electronic mail system can be partly carried out by a mainframe computer and partly by personal computers, and it might be useless to makedistinctions on this basis; however, the computer communications function and the text creation function could be seen as different sub-systems and their economic performance ratios calculated separately.

VI) Given the complexity of organizations, any technological change can have repercussions on various sectors and impact assessment should not be restricted to the sectors affected by the change.

To be effective, providing secretarial staff with a word processing system should lead to higher productivity in text originators, and improvements in a supply department should have positive effects on the productivity of the mainlinedepartments it serves.

VII) To obtain precise measurements of the costs related to technology, periodic data gathering mechanisms must be put in place on various factors, such as how employees spend their time. However, an accurate evaluation of benefits must be done periodically by user managers with respect to concrete, standard situations. The results of these measurements, translated into monetary terms, for all components and over several time periods give the economic indicators.

VIII) Although measurement mechanisms can be established for several years, they can be reviewed regularly to take account of changes in the organization's policies, strategy, orientation or objectives. Co-operative review structures have to be set up (steering committee, task forces) involving the active participation of certain managers.

9. Conclusion

When we began our work at the Canadian Workplace Automation Research Centre we felt that it would be possible to identify an efficient, effective approach to assessing productivity related to the use of information processing in most organizations by synthesizing various existing models and using all the material in the extensive scientific literature on the subject as a partial pre-validation of this approach. Accordingly, in addition to the fruits of our literature review, we expected to use the findings of our own projects and to draw on the results of two major federal government initiatives, the Office Communications Systems Program and the Treasury Board Task Force on Informatics.

We found that although the scientific literature offered various models, very few of them had actually been put into application and produced significantly valid measures that could be transposed to other contexts. The same can be said of the results of the work done under the Office Communications SystemsProgram; although models were developed under it and the Program was probably very useful to hardware and software manufacturers who were able to verify and adapt some of their products, we found practically no productivity measurement. We were only able toconsult a few of the Task Force on Informatics' reports because their distribution was restricted by the Treasury Board.

To get a better overview of the subject, we felt it necessary to conduct a survey of over 50 large organizations to find out how planning was done for the different aspects of EDP, including productivity measurement, and what the main characteristics were of the productivity gauges used, where applicable; we therefore gathered the views of several dozen managers (EDP, users). We had already developed a cost/benefit analysis model that computes a set of economic indicators for each system individually and all the systems overall.

From what we distilled from our extensive reading and meetings with other researchers and our own projects, we were able to identify the basic principles of an economic approach to the measurement of productivity and other impacts of the introduction of new technology. This approach is shortly to be validated in practice in a parapublic institution.

We hope that this work has made a useful contribution to the field of EDP management and thrown new light on the impacts of computerization on society. We wish to thank once again all the people and organizations who contributed to it.

10. References

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